STAT 419 Course Project: NHANES

Group 5

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Section A: Introduction/Background

The National Health and Nutritional Examination Survey provided information for this data set. The information was collected on adults who are at an age of 20 years or older between the years of 1988 and 1994.

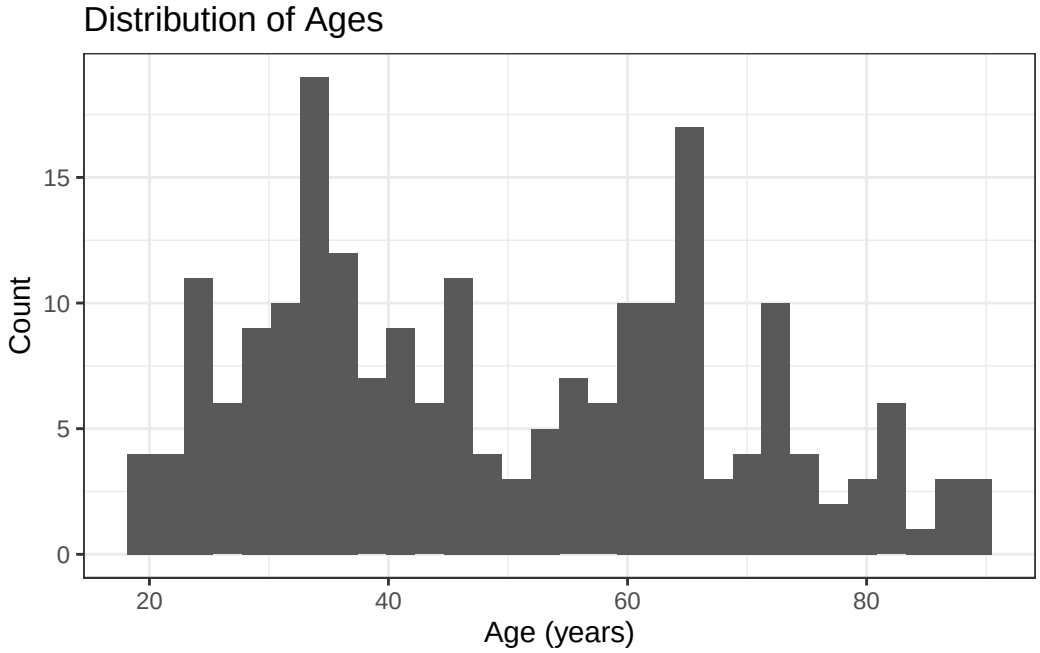
The goal of this data set is to provide the Blood Pressure Rank, measured by variable SBPRANK, for each subject in the Data Set. SBPRank is the grouping variable that is determined by average systolic blood pressure (AVGSBP). The values for SBPRank include 1,2, and 3. 1 is the lowest blood pressure rank indicated by low values of AVGSBP and 3 is the highest blood pressure rank indicated by high values of AVGSBP. 2 is the blood pressure ranking for average systolic blood pressure in the middle ranges.

The other variables in the data set includes:

- HSAGEIR: Subject age recorded in years.
- BMPWTLBS: Subject body weight in pounds.
- BMPHTIN: Subject standing height in inches.
- PEPMNK5R: Subject average diastolic blood pressure
- TCP: This is a measure of the Subject Serum Cholesterol.

Section B: Graphs and Summary Statistics

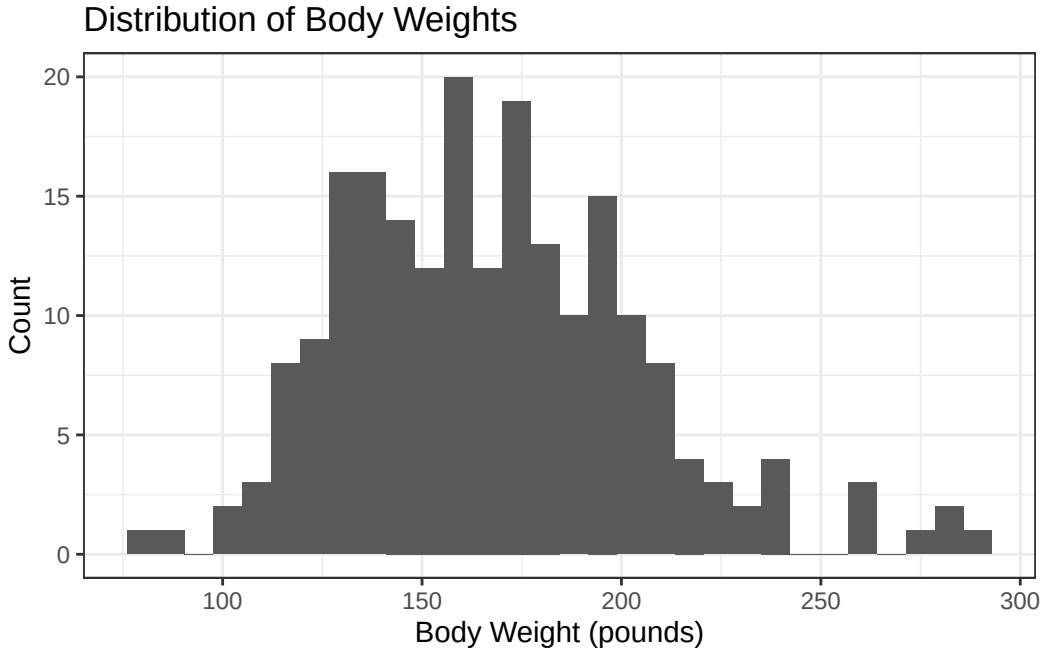
HSAGEIR




```
      Mean Median Standard.Deviation
1 49.44019     46           18.51993
```

With a mean of 49.44 years, a median of 46 years, and a standard deviation of 18.52 years, the ages in the `nhanes` dataset range from 20 to 90 years old. The distribution of ages appears to be slightly right-skewed and bimodal, with peaks around 35 and 65 years.

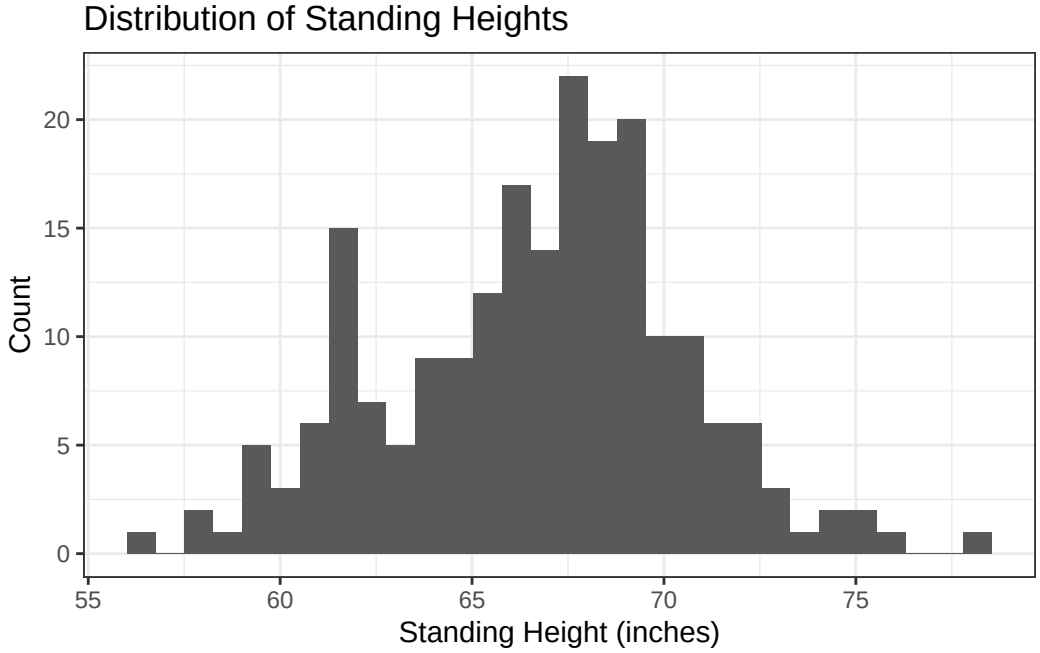
BMPWTLBS




```
      Mean Median Standard.Deviation
1 167.5651    163           37.55311
```

With a mean of 167.57 pounds, a median of 163 pounds, and a standard deviation of 37.55 pounds, the body weights in the `nhanes` dataset range from roughly 80 to 300 pounds. The distribution of body weights appears to be unimodal and slightly right-skewed, with some potential outliers in both directions.

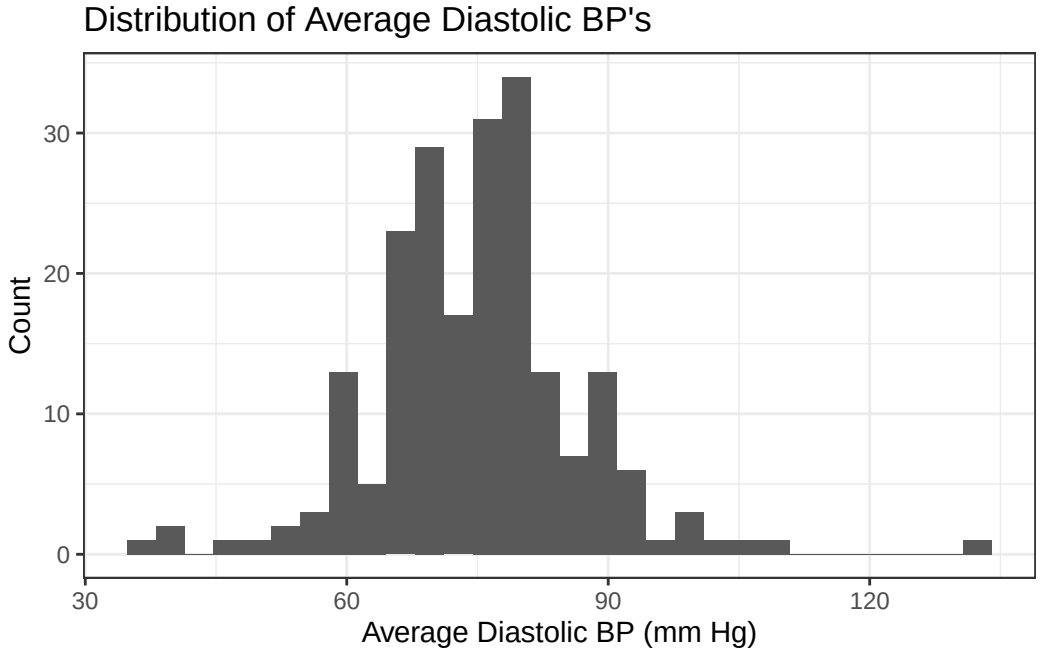
BMPHTIN




```
     Mean Median Standard.Deviation
1 66.6933   67.2           3.816759
```

With a mean of 66.69 inches, a median of 67.2 inches, and a standard deviation of 3.82 inches, the standing heights in the `nhanes` dataset range from roughly 55 to 80 inches. The distribution of standing heights appears to be unimodal and fairly symmetric (perhaps slightly left-skewed), with some potential higher outliers.

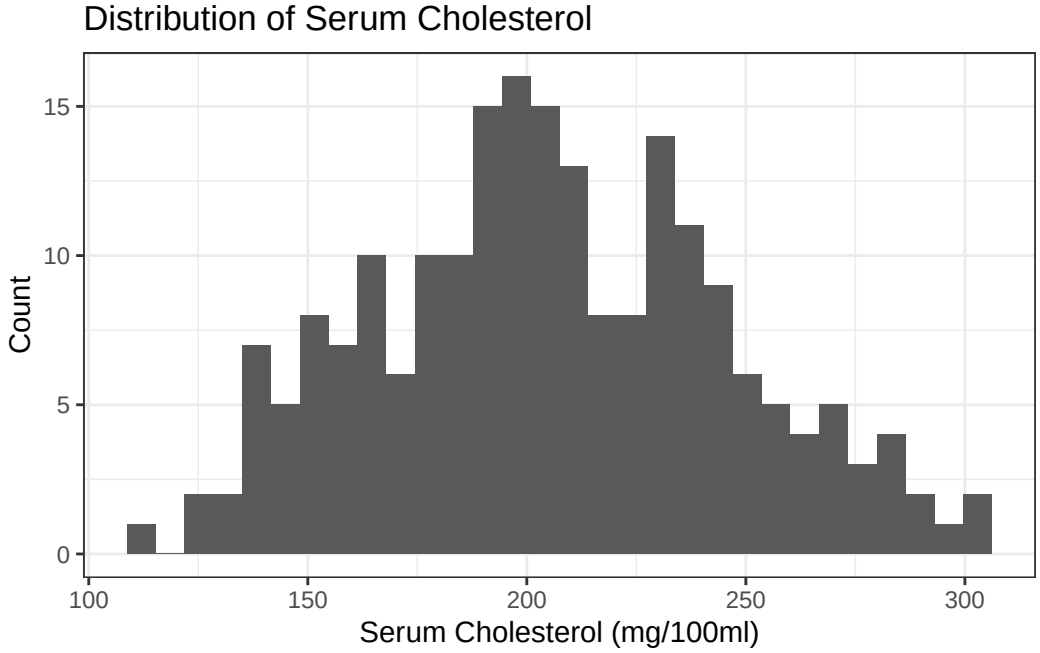
PEPMNK5R




```
      Mean Median Standard.Deviation
1 74.90909     75           11.79498
```

With a mean of 74.91 mm Hg, a median of 75 mg Hg, and a standard deviation of 11.79, the average diastolic bp in the `nhanes` dataset range from roughly 35 to 135 mm Hg. The distribution of average diastolic bps appears to be unimodal and fairly symmetric, with some clear outliers in the 130's.

TCP




```
      Mean Median Standard.Deviation
1 205.6268    203           40.30144
```

With a mean of 205.63 mg/100ml, a median of 203 mg/100ml, and a standard deviation of 40.30, the serum cholesterols in the `nhanes` dataset range from roughly 110 to 300 mg/100ml. The distribution of serum cholesterols appears to be roughly unimodal (with a slight drop in the 200's) and slightly right-skewed, with no clear outliers.

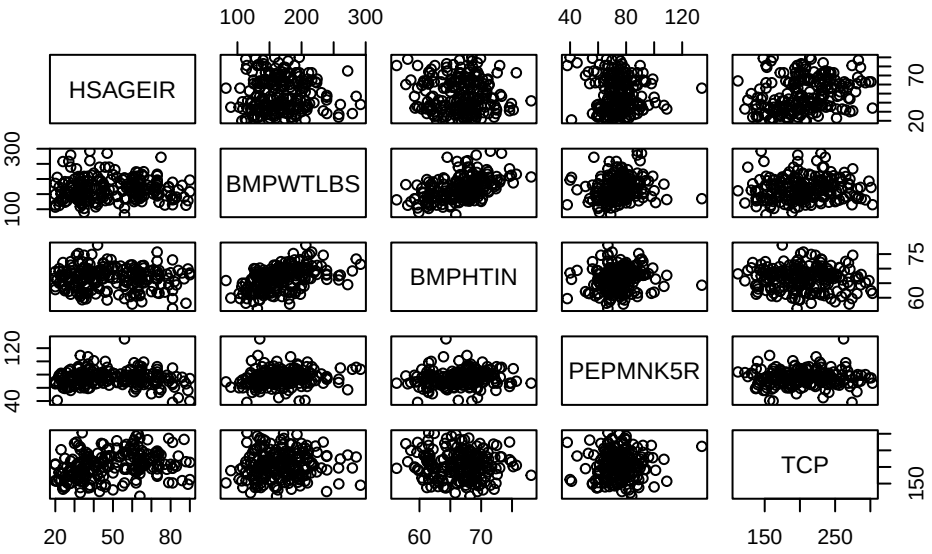
Section C: Discriminant and Classification Analysis

C.1: Correlated Quantitative Variables (Multicollinearity)

The Correlation Coefficient Tables for between quantitative variables in the NHANES data set are below:

	HSAGEIR	BMPWTLBS	BMPHTIN	PEPMNK5R	TCP
HSAGEIR	1.000000000	-0.008383008	-0.06742182	-0.0729738	0.28193987
BMPWTLBS	-0.008383008	1.000000000	0.48165357	0.1720942	0.08077624
BMPHTIN	-0.067421821	0.481653572	1.00000000	0.1387325	-0.06180148
PEPMNK5R	-0.072973801	0.172094241	0.13873253	1.0000000	0.04779740
TCP	0.281939870	0.080776245	-0.06180148	0.0477974	1.00000000

The Scatter Plots representing correlations between the quantitative variables in the NHANES data set are below:



C.2: Discriminant Analysis

```
           [,1]      [,2]
[1,] -10.784324 -8.677779
[2,]  -3.772346  7.113163
[3,]  -7.754878  8.769770
[4,]   2.881487  2.341885
```

Let:

- y_1 = HSAGEIR (Age) (variable 2)
- y_2 = BMPWTLBS (Body Weight) (variable 3)
- y_3 = PEPMNK5R (Average Diastolic BP) (variable 5)
- y_4 = TCP (Serum Cholesterol) (variable 6)

Then the standardized discriminant functions are:

$$LD_1(y) = -10.784y_1 - 3.772y_2 - 7.755y_3 + 2.881y_4$$

$$LD_2(y) = -8.678y_1 + 7.113y_2 + 8.770y_3 + 2.342y_4$$

We now rank the standardized coefficients of each discriminant function, LD_1 and LD_2, by observing their absolute values.

For the first discriminant function (LD_1), y_1 (age) and y_3 (average diastolic BP) are the most important for separating the groups, followed by y_2 (body weight) and y_4 (cholesterol): $y_1 \to y_3 \to y_2 \to y_4$.

For the second discriminant function (LD_2), y_3, y_1, and y_2 are the most important, followed by y_4: $y_3 \to y_1 \to y_2 \to y_4$.

Significance Tests for Discriminant Functions

```
       Lambda          V   p.values
LD1 0.4856068 147.721810 0.00000000
LD2 0.9596942   8.413261 0.03820007
```

Hypotheses:

- 1st Test (for LD_1):
  - H_0: $\alpha_1 = \alpha_2 = 0$
  - H_a: At least one $\alpha_i \neq 0$

- 2nd Test (for LD_2):
  - H_0: $\alpha_2 = 0$
  - H_a: $\alpha_2 \neq 0$

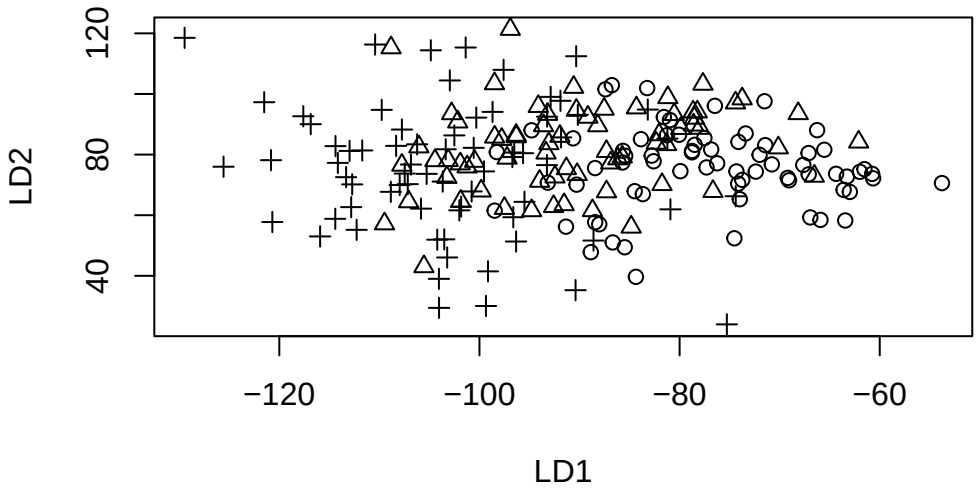
Conclusions:

- blabla..

Significance Tests for Additional Variables

```
            Lambda    F.stat      p.value
HSAGEIR  0.6046790 66.357652 0.000000e+00
PEPMNK5R 0.7659335 31.018029 1.759481e-12
BMPWTLBS 0.9344024  7.125580 1.021397e-03
TCP      0.9679940  3.356017 3.681948e-02
```

Visualizing Discriminant Functions



C.3: Classification Analysis

Four most significant variables

Classification Analysis

```
$coefs
          [,1]      [,2]      [,3]       [,4]
[1,] 0.2916651 0.1120130 0.6792672 0.07939680
[2,] 0.3555073 0.1287796 0.7809797 0.07280753
[3,] 0.4457149 0.1350911 0.8384779 0.06346110

$c.0
[1] -45.52791 -57.05103 -65.63240
```

Given:

- y_1 = Age (Variable 2)
- y_2 = Body Weight (Variable 3)
- y_3 = Average Diastolic BP (Variable 5)
- y_4 = Serum Cholesterol (Variable 6)

Then:

$$L_1(y) = 0.292y_1 + 0.112y_2 + 0.679y_3 + 0.079y_4 - 45.528$$

$$L_2(y) = 0.356y_1 + 0.129y_2 + 0.781y_3 + 0.073y_4 - 57.051$$

$$L_3(y) = 0.446y_1 + 0.135y_2 + 0.838y_3 + 0.063y_4 - 65.632$$

Assign to G_1, G_2, or G_3 depending on if $L_1(y)$, $L_2(y)$, or $L_3(y)$ respectively yields the greatest value for a given observation.

Apply Classification to Observation 1

Observation 1, eliminating height:

nhanes(1)'= (63 141.4 64 20)

```
         [,1]
[1,] 49.62603
```

```
         [,1]
[1,] 49.55572
```

```
         [,1]
[1,] 49.17355
```

For a single observation, the linear classification function with the greatest returned value is considered to be assigned to that group. For the first observation, the first linear classification function returned the greatest value of 49.626, indicating that the observation be correctly classified as part of Group 1.

This is very similar to the values of other functions $L_2(y)$ and $L_3(y)$ (49.556 and 49.174 respectively), which could indicate a large amount of noise in the data. Non-linear classification functions might explain separation of groups better if further analysis were to be conducted.

Confusion Matrix

```
$`Correct Class Rate`
[1] 0.6363636

$`Error Rate`
[1] 0.3636364

$Method
[1] "LDA"

$`Confusion Matrix`
         predicted
original  1  2  3
       1 51 15  3
       2 18 32 20
       3  5 15 50
```

ACCR = 63.64%

AER = 36.36%

The linear classification functions are classifying the majority of observations correctly (64%), but there is some classification error (36%). This supports earlier conclusions of high noise within the data leading to some incorrectly classified observations.

Section D: Summary

In our analysis of the National Health and Nutrition Examination Survey, we analyzed the five variables measured on each subject of the survey, age, body weight (lbs), height (in), average diastolic blood pressure, and serum cholesterol. Using blood pressure rank - categorized into three groups (one, two, and three) - as the grouping variable, we performed discriminant and classification analysis.

In section B we found that while the ages of subjects from the survey range from 20 to 90, most were around the ages of 35 and 65 seen by the two bimodal peaks. The average weight across subjects was approximately 167 pounds and the average height around 67 inches. Interestingly, the distribution of the average diastolic blood pressure was roughly bell shaped and centered around 74.91 mm Hg. The average serum cholesterol levels were around 205.63 mg/100ml.

Prior to creating the correlation matrix and correlation plots, we believed that height and weight, age and weight, age and average diastolic blood, and weight and serum cholesterol, may have moderate correlations. In section C1 we were surprised to see relatively moderate to weak correlations between each of the five variables from the dataset. The correlation between height and weight was the highest of all the correlations at 0.48, thus we omitted the height variable from further analysis in sections C2 and C3. The next highest correlation was between age and serum cholesterol level at 0.28. Here, since the correlation was weak, we did not omit either variable. Correlations coefficients between all other variables were smaller than 0.2 and greater than -0.1, which we classified as weak.

In C2, the standardized coefficients from the first linear discriminant function indicated that age and average diastolic blood pressure were the most important variables in separating the blood pressure rank groups. The second linear discriminant function also indicated these two variables were most important. After conducting a significance test for discriminant functions we found that only the first function was statistically significant at the adjusted significance level of $\alpha = 0.025$. The partial F-test conducted at $\alpha = 0.0125$ reflected the same ordering of the variables from most important to least important - age, average diastolic blood pressure, body weight, and serum cholesterol - as seen from the coefficients in the first linear discriminant function. Since the p-value for serum cholesterol was greater than 0.0125, we concluded that it was not a significant contributor. Furthermore, the discriminant plot supported our analysis as it showed clearer separation between blood pressure rank groups from the first linear discriminant function than the second function.

After creating the linear classification functions for each of the three blood pressure rank groups, we were able to correctly classify the first subject into group one. While the function for group one produced the highest score, we noted that all three functions produced similar values. This was supported by our confusion matrix and accuracy measures. Our apparent correct classification rate was 63.64%, suggesting a moderate number of misclassifications.

One challenge was determining whether the correlation of 0.48 between height and weight was strong enough to omit height from the analysis to avoid multicollinearity. Ultimately, we

decided to omit the variable out of an abundance of caution. If we were to do this project again, we could have done one set of analyses with the height variable and one without to compare results. Additionally, a variable such as cortisol level could have been useful in group separation. Since stress is a big factor in blood pressure and can be measured through cortisol level, it would have been interesting to conduct the analysis with this variable and see how group separation reacted as a result.

Section E: R Code

Setup

```
library(tidyverse)
source("all_customized_functions.R")
nhanes <- read.csv(here::here("NHANES3_419.csv"), header = TRUE)
```

Section B

```
# HSAGEIR
nhanes |>
  ggplot(aes(x = HSAGEIR)) +
  geom_histogram() +
  labs(x = "Age (years)", y = "Count", title = "Distribution of Ages") +
  theme_bw()

data.frame(Mean = mean(nhanes$HSAGEIR), Median = median(nhanes$HSAGEIR),
           `Standard Deviation` = sd(nhanes$HSAGEIR))

# BMPWTLBS
nhanes |>
  ggplot(aes(x = BMPWTLBS)) +
  geom_histogram() +
  labs(x = "Body Weight (pounds)", y = "Count",
       title = "Distribution of Body Weights") +
  theme_bw()

data.frame(Mean = mean(nhanes$BMPWTLBS), Median = median(nhanes$BMPWTLBS),
           `Standard Deviation` = sd(nhanes$BMPWTLBS))

# BMPHTIN
nhanes |>
  ggplot(aes(x = BMPHTIN)) +
  geom_histogram() +
  labs(x = "Standing Height (inches)", y = "Count",
       title = "Distribution of Standing Heights") +
  theme_bw()
```

```r
data.frame(Mean = mean(nhanes$BMPHTIN), Median = median(nhanes$BMPHTIN),
           `Standard Deviation` = sd(nhanes$BMPHTIN))

# PEPMNK5R
nhanes |>
  ggplot(aes(x = PEPMNK5R)) +
  geom_histogram() +
  labs(x = "Average Diastolic BP (mm Hg)", y = "Count",
       title = "Distribution of Average Diastolic BP's") +
  theme_bw()

data.frame(Mean = mean(nhanes$PEPMNK5R), Median = median(nhanes$PEPMNK5R),
           `Standard Deviation` = sd(nhanes$PEPMNK5R))

# TCP
nhanes |>
  ggplot(aes(x = TCP)) +
  geom_histogram() +
  labs(x = "Serum Cholesterol (mg/100ml)", y = "Count",
       title = "Distribution of Serum Cholesterol") +
  theme_bw()

data.frame(Mean = mean(nhanes$TCP), Median = median(nhanes$TCP),
           `Standard Deviation` = sd(nhanes$TCP))
```

Section C1

```r
NHANESData <- nhanes |>
  select(-1)

# correlation table
cor(NHANESData)

# scatter plot
plot(NHANESData)
```

Section C2

```
nhanes_c2 <- nhanes
nhanes_c2$SBPRANK <- as.factor(nhanes$SBPRANK)
# Omit height variable
nhanes_c2 <- nhanes_c2[, c("SBPRANK", "HSAGEIR", "BMPWTLBS",
                           "PEPMNK5R", "TCP")]

X <- nhanes_c2[, -1]
y <- nhanes_c2[, 1]

# discriminant analysis
discrim(X, y)$a.stand

# significance tests for discriminant functions
discr.sig(X, y)

# significance tests for additional variables
partial.F(X, y)

# visualizing discriminant functions
discr.plot(X, y)
```

Section C3

```
nhanes_c3 <- nhanes
# Omit height
data <- nhanes_c3[,-4]

# classification analysis
lin.class(data[,-1], data[,1])

# apply classification to observation 1
L1 <-  0.2916651%*%(63) + 0.1120130%*%(141.4) + 0.6792672%*%(64)
+ 0.07939680%*%(220) - 45.52791
L2 <-  0.3555073%*%(63) + 0.1287796%*%(141.4) + 0.7809797%*%(64)
+ 0.07280753%*%(220) - 57.05103
L3 <-  0.4457149%*%(63) + 0.1350911%*%(141.4) + 0.8384779%*%(64)
+ 0.0634611%*%(220) - 65.63240
```

```
L1
L2
L3

# confusion matrix
rates(data[,-1], data[,1])
```